DEVICES AND METHODS FOR PROTECTING WINDINGS AROUND A SHARP EDGED CORE

Field of the Invention

The present invention relates to protection devices and, more particularly, to devices and methods for protecting windings.

Background of the Invention

A variety of different products are known which require wrapping of windings around a core member having an opening therein. Example of such products include electromagnetic sensor equipment and electrical transformers. Such products typically include a cylindrical shaped metal core having electrically conductive wires wrapped around the core.

As the conductive core and the electrically conductive wires typically must be isolated, the wires in such products are often coated, for example, with a varnish or other insulating coating. However, it is often desirable, for manufacturing and/or performance reasons, to utilize a sharp edged core with right angle interfaces at each of the outer and inner corner surfaces of the core around which the wires must be wrapped. These edges may cut into the wiring and undesirably introduce an electrically conductive path between the core and the wrapped wiring. Accordingly, various approaches have been proposed for protecting the wrapped wiring.

In one prior art approach, a non-conductive paper is placed around the core before the wire is wrapped around the core. For example, sheet cardboard may be cut to provide two circular portions with outer diameter and inner diameter values selected to correspond to the end faces of the core. A first and second rectangular

strip are also cut with lengths corresponding to the circumference of the core at the respective outer diameter of the core and the diameter of the opening in the center of the core through which the wires will pass and a width corresponding to the width of the core between its end faces. These four pieces are then positioned around the outer surface of the core and taped in place. The wire (typically ranging from about 8 AWG to about 32 AWG) may then generally be safely wrapped around the core without damaging the insulating coating (for example, varnish) of the wire. However, due, in part, to the variety of different diameters (typically about 4 inches (10.16 centimeters) to about 44 inches (111.76 centimeters)) and widths (typically about 1.25 inches (3.175 centimeters) to about 8.5 inches (21.59 centimeters)) of the cores, a great deal of waste is typically encountered using the non-conductive paper wrapping. For example, the cut out of the center of the rings for the end pieces must, typically, be scrapped along with the outer portions of the material after the end pieces are cut out. The taping operation provides additional expense in materials and labor as well.

An alternative approach has been proposed in which a 90 degree plastic extrusion with two equal length sides is placed over the corners of the core. However, a problem with this approach is the tendency of the material to have uneven sides due to the wrapping of the extrusion around the circumference of the core, particularly on the edges of the inner opening of the core. This problem may be particularly acute for smaller diameter cores. In addition, an overlap of the ends of the extrusion to complete the wrap of the circumference without leaving any exposed sharp edges would result in an undesirable bump on the surface which, like the rippling caused by the wrapping of the extrusion into a circular configuration, could adversely affect performance of the finished electromagnetic product.

Summary of the Invention

According to embodiments of the present invention, electromagnetic devices are provided including an electrically conductive core having an inner diameter defining an opening therethrough and an outer diameter, the core having sharp edges extending circumferentially around the inner diameter and around the outer diameter thereof. A plurality of polymeric protection members are wrapped circumferentially around the core and positioned adjacent the sharp edges of the core. An adhesive layer is positioned between the protection members and the core connecting the

protection members to the core. A coated wire is wrapped around the core so as to be magnetically coupled thereto and around the polymeric protection members so as to be displaced from the sharp edges of the core.

In further embodiments of the present invention, electromagnetic devices are provided including an electrically conductive core having an inner diameter defining an opening therethrough and an outer diameter, the core having sharp edges extending circumferentially around the inner diameter and around the outer diameter thereof. A plurality of polymeric protection members are wrapped circumferentially around the core and positioned adjacent the sharp edges of the core. The protection members have at least one short leg positioned adjacent at least one end of the core. The short leg has a length selected to provide a substantially flat surface on the end of the core when the protection members are wrapped around the core. A coated wire is wrapped around the core so as to be magnetically coupled thereto and around the polymeric protection members so as to be displaced from the sharp edges of the core.

In other embodiments of the present invention, the protection members are L-shaped strips having a short leg positioned adjacent an end of the core and a long leg positioned adjacent a circumferential face of the core. The short leg has a length selected to provide a substantially flat surface on the end of the core. In alternative embodiments of the present invention, the protection members are channel shaped members having a width at least equal to a width of the core and a first and second leg at opposite sides thereof and a channel portion extending therebetween. The channel shaped members are wrapped around the core so as to position the first leg adjacent a first end of the core and the second leg adjacent an opposite end of the core with a circumferential face of the core positioned in the channel shaped member.

In further embodiments of the present invention, the adhesive layer is positioned adjacent the short leg of the protection members. The long leg and/or channel portion of the protection members may directly contact the core without an adhesive layer therebetween. The protection members may further include a first end and a second end thereof, the first end and second end defining mating angles at an overlapping region of the protection members when the protection members are wrapped around the core so as to extend around the entirety of one of the sharp edges of the core without a bump discontinuity at the overlapping region. The mating

angles may be between about 15 degrees and 75 degrees and, in further embodiments, may be 45 degree angles.

In other embodiments of the present invention, the outer diameter of the core is at least about 5 centimeters (3 inches) and the first and second leg each have a length of less than about .32 centimeters (.125 inches). In further embodiments, the outer diameter of the core is at least about 22 centimeters (9 inches) and the first and second leg each have a length of less than about 1 centimeter (.375 inches).

In further embodiments of the present invention, the protection members are a crosslinked polymeric material having a dielectric strength selected to limit breakdown of the protection members by magnetic fields generated around the core. The dielectric strength may be at least about 200 volts/centimeter. The polymeric material may be stable at 150 degrees Centigrade for at least about 100 hours. The crosslinked polymeric material may be either medium or high density polyethylene.

In a further aspect of the present invention, protection members are provided for a device including a sharp-edged core and elongate members wrapped therearound. The protection member is an L-shaped strip having a short leg configured to be positioned adjacent an end of the core, abutting a circumferentially extending sharp edge of the core, and a long leg extending substantially transversely from the short leg so as to be positioned adjacent a circumferential face of the core. The short leg has a length selected to provide a substantially flat surface on the end of the core when wrapped around the core. Alternatively, the protection members may be channel shaped members having a width at least equal to a width of the core and a first and second leg at opposite sides thereof and a channel portion extending therebetween, the channel shaped members being configured to be wrapped around the core so as to position the first leg adjacent a first end of the core and the second leg adjacent an opposite end of the core with a circumferential face of the core positioned in the channel shaped member. The first and second legs each have a length selected to provide a substantially flat surface on the end of the core when wrapped around the core. The device may be an electromagnetic device and the elongate members may be wires having an insulating coating thereon.

In yet another aspect of the present invention, methods are provided for assembling an electromagnetic device including a sharp-edged core and at least one wire wrapped therearound. Polymeric protection members are placed around sharp edges of the core extending circumferentially around an inner diameter and around an outer

diameter of the core. The protection members have a short leg positioned adjacent an end of the core. The short leg has a length selected to provide a substantially flat surface on the end of the core when the protection members are wrapped around the core. A wire is wrapped around the core so as to be magnetically coupled thereto and around the polymeric protection members so as to be displaced from the sharp edges of the core. An adhesive layer may be placed on an inner surface of the polymeric protection members to secure the polymeric protection members to the core.

In another aspect of the present invention, methods are provided for fabricating a polymeric protection member for a device including a core having circumferentially extending sharp edges around an inner diameter and around an outer diameter thereof around which elongate members are wrapped. A circumferential length of one of the sharp edges is determined. A length of a polymeric protection strip stock is measured out corresponding to the determined circumferential length. The polymeric protection strip stock is cut to the measured length to provide the protection member. More particularly, the polymeric protection strip stock is cut at an angle selected to define mating angles at an overlapping region of the protection member when the cut protection member is wrapped around the core so as to extend around the entirety of one of the sharp edges of the core without a bump discontinuity at the overlapping region. The angle may be between about 15 degrees and about 75 degrees. The polymeric protection strip stock may have at least one short leg configured to be positioned adjacent at least one end of the core. The short leg may have a length selected to provide a substantially flat surface on the end of the core when the polymeric protection member is wrapped around the core.

In further embodiments of the present invention, electromagnetic devices are provided including an electrically conductive core having at least one circumferentially extending sharp edge. At least one polymeric protection member is wrapped circumferentially around the core and positioned adjacent the at least one circumferentially extending sharp edge of the core. The at least one protection member further includes a first end and a second end thereof, the first end and second end defining mating angles at an overlapping region of the at least one protection member when the protection member is wrapped around the core so as to extend around the entirety of the at least one circumferentially extending sharp edge of the core without a bump discontinuity at the overlapping region. An insulated wire is

wrapped around the core so as to be magnetically coupled thereto and around the at least one polymeric protection member so as to be displaced from the at least one circumferentially extending sharp edge of the core. In such embodiments including mating angles, the protection member(s) may comprise L-shaped members with a short leg positioned adjacent an end face of the core and a long leg extending substantially transversely therefrom, channel shaped members, L-shaped members with the long leg positioned adjacent the end face of the core and/or angled members with equal length legs.

Objects of the present invention will be appreciated by those of ordinary skill in the art from a reading of the figures and the detailed description of the preferred embodiments which follow, such description being merely illustrative of the present invention.

Brief Description of the Drawings

The accompanying drawings which form a part of the specification, illustrate key embodiments of the present invention. The drawings and description together serve to fully explain the invention.. In the drawings,

Figure 1 is a perspective view of a core of an electromagnetic device;

Figure 2 is a perspective view of an electromagnetic device including the core of **Figure 1**;

Figure 3A is a perspective view of a protection member partially wrapped around a core of an electromagnetic device according to embodiments of the present invention;

Figure 3B is a perspective view of a protection member partially wrapped around a core of an electromagnetic device according to further embodiments of the present invention;

Figure 4A is a perspective view of an electromagnetic device including protection members according to embodiments of the present invention;

Figure 4B is a perspective view of an electromagnetic device including protection members according to further embodiments of the present invention;

Figure 4C is a side elevational view of the overlap point of one of the protection devices illustrated in **Figure 4A**;

Figure 5A is a perspective view of a protection member according to embodiments of the present invention;

Figure 5B is a perspective view of a protection member according to further embodiments of the present invention;

Figure 6 is a perspective view of a protection member according to yet further embodiments of the present invention;

Figure 7 is a side elevational view of a protection member fabrication apparatus according to embodiments of the present invention;

Figure 8 is a flowchart illustrating operations for assembling an electromagnetic device according to embodiments of the present invention; and

Figure 9 is a flowchart illustrating operations for fabricating a protection member according to embodiments of the present invention.

Detailed Description of the Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements throughout. The terms “upwardly”, “downwardly”, “vertical”, “horizontal” and the like are used herein for the purpose of explanation only.

Referring now to **Figure 1**, a core of a device, such as an electromagnetic device, with which protection members of the present invention may be used, will be described to provide a background for further describing the present invention. As shown in the embodiment of **Figure 1**, a generally cylindrical core **100** is illustrated. However, it is to be understood that the core need not be circular in profile and may take on other shapes, such as elliptical or other shapes having circumferentially extending sharp edges. For the purposes of simplicity and understanding of the present invention, however, the description of the present invention herein will generally make reference to a circular profile core such as that illustrated in **Figure 1**.

As shown in **Figure 1**, the core **100** includes an inner diameter (ID) defining an opening **105** through the core **100**. The core is further defined by an outer diameter (OD). Two end (or side) faces **110**, **115** are illustrated displaced from each other by a width (W). A circumferential face **120** extends around the core which has a width (W) and a length corresponding to the circumference of the core **100**.

An electromagnetic device **200** including a core such as that shown in **Figure 1** is illustrated in **Figure 2**. The electromagnetic device **200** includes a non-conductive paper wrapped core **205** and an inner diameter defining an opening **210** therethrough. One or more wires **215** are wrapped around the core **205** and terminate in respective end connectors **220**, **225**. It is to be understood that the electromagnetic device **200** as shown in **Figure 2** includes a conventional non-conductive paper wrap for protecting the wires **215** from contact with the circumferentially extending sharp edges at the inner diameter and outer diameter of the core **205**. Such wires may be provided with an insulating coating, such as a varnish.

Referring now to the illustration of **Figure 3A**, embodiments of protective members in accordance with the present invention being wrapped around a sharp edged core will be further described. **Figure 3A** illustrates a partial assembly **300** including, on the top face of a core **302** as shown in **Figure 3A**, a circumferentially extending sharp edge along an inner diameter **310** covered by first protective member **305'**. A second circumferentially extending sharp edge **320** is illustrated extending around the outer diameter of the core **302**. A circumferentially extending face **315** of the core **302** extends between the end or side shown as the top of the assembly **300** in **Figure 3** and the opposite end which is not visible in **Figure 3A**. A protection member **305** is partially wrapped around the edge **320** in **Figure 3A**. As shown in **Figure 3A**, the protection member **305** is an L-shaped strip having a short leg positioned adjacent the end or side face of the core **302** and a long leg (*i.e.*, longer than the short leg) positioned adjacent the circumferential face **315** of the core **302**. Preferably, the short leg **309** has a length selected to provide a substantially flat surface on the end (or side) of the core **302**. The long leg **307** may have a length selected to facilitate mounting and retention of the L-shaped member **305** on the core **302**.

Referring now to **Figure 3B**, further embodiments of protection members for wrapping around sharp edged cores will now be described. As shown in **Figure 3B**,

the assembly **350** includes a single protection member **355** partially wrapped around the outer diameter of a core **352**. The core **352** includes an inner diameter defining an opening **360** therethrough. The core **352** includes two circumferentially extending sharp edges **370, 370'** extending around the outer circumference of the core **352** with a circumferential face **365** therebetween.

As shown for the embodiments of **Figure 3B**, the protection member **355** is a channel or rail shaped member having a width at least equal to the width of the circumferential face **365** of the core **352** so as to slip or press fit over the face **365** of the core **352**. The channel shaped protection member **355** includes a first leg **359** and a second leg **359'** at opposite sides thereof and a channel portion **357** extending between the first and second legs, **359, 359'**. The channel shaped protection member **355** is wrapped around the core **352** so as to position the first leg **359** adjacent the top end/side of the core **352** along the sharp edge **370** and to place the second leg **359'** adjacent an opposite end/side of the core **352** defining the second sharp edge **370'**. The circumferential face **365** of the core **352** is positioned within the channel defined by the channel shaped member **355** abutting the channel portion **357**. While no protection member **355** is shown covering the sharp edges defined by the inner diameter around the opening **360** in **Figure 3B**, it is to be understood that the protection member **355** may be inverted and provided in a different length but, otherwise, be applied in the same manner to protect the inner diameter circumferentially extending sharp edges **361** as described with respect to the outer sharp edges **370, 370'**.

The respective ends of the protection member **355** define mating angles which will overlap when the protection member **355** is fully wrapped around the core **352** so as to extend the protection member **355** around the entirety of the sharp edges **370, 370'** without a bump discontinuity being presented in the overlapping region. For the embodiment illustrated in **Figure 3B**, the mating angle is a 45 degree angle as will be further described with reference to **Figure 4C**.

The protection member **305** or **355** may be provided as an extruded plastic profile. As will be further described herein, the extruded profile can also have one surface coated with a high tack adhesive or other mastic bonding substrate to provide an adhesive layer for coupling the protection member **305, 355** to the core. Such an

extruded profile may be supplied as a continuous wrap reeled, for example, on a large spool.

For electromagnetic devices, such as sensors or transformers, a broad range of outer diameters for the core may be encountered. It is preferred that the legs **309, 359, 359'** adjacent the end faces of the core in such devices have lengths selected to provide a substantially flat surface on the ends of the core when the protection members **305, 355** are wrapped around the core. More particularly, an excessive length of the legs **309, 359, 359'**, relative to the bend radius introduced based on the diameter of the core where the protection member is utilized, may cause a ripping of the leg **309, 359, 359'** along the ends which may be undesirable for the performance of the resulting device. In various embodiments of the present invention, where the outer diameter (*i.e.*, the diameter at which the protection member is to be applied) is at least about 5 centimeters (3 inches), the short leg has a length of less than about .32 centimeters (.125 inches). In further embodiments, the outer diameter of the core is at least about 22 centimeters (9 inches) and the short leg has a length of less than about 2 centimeters (3/4 inches) and, more preferably, less than about 1 centimeter (.375 inches). The protection member may have a material thickness of between about 1 millimeter and about 3 millimeters.

The adhesive layer between the protection member **305, 355** and the core **302, 352** may be positioned adjacent the short leg **309, 359, 359'** of the protection members **305, 355**. The long leg **307** of the protection member **305** and/or the channel portion **357** of the protection member **355** may directly contact the core without an adhesive layer therebetween in various embodiments of the present invention.

The material used in the forming of the protection members **305, 355** may be a crosslinked polymeric material. The crosslinked polymeric material preferably has a dielectric strength selected to limit breakdown of the protection members by magnetic fields generated around the core. The dielectric strength may, for example, be at least about 200 volts/centimeter and, more preferably, may be about 217 volts/centimeter with a material thickness of 1.27 millimeters for the protection members. The crosslinked polymeric material may be a medium or high density polyethylene material or other suitable material.

Further material properties for the protection members **305, 355** which may be beneficial in various applications include heat stability at 150 degrees Centigrade for at least about 100 hours and, more preferably, for about 168 hours. The thermal endurance of the polymeric material may be about 20,000 hours at 105 degrees Centigrade. The abrasion resistance for the polymeric crosslinked material may be 20% maximum material loss after 1,000 cycles at 2068 grams. The crosslinked polymeric material may further have a low temperature impact resistance down to about -20 degrees Centigrade.

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Referring now to the illustration of **Figure 4A**, the assembly **300** of **Figure 3A** with protection members **305** positioned around all sharp edges of the core **302** and a wire **440** wrapped therearound is illustrated. The wire **440** further includes end connectors **442, 444**. Otherwise, like numbered elements shown in **Figure 4A** correspond to similarly numbered elements of **Figure 3A** and will not be further described herein. Similarly, **Figure 4B** illustrates the assembly **350** of **Figure 3B** with a protection member **355** fully positioned around both the outer diameter sharp edges and the inner diameter sharp edges and a wire **490** wrapped thereabouts. The wire **490** includes end connectors **492, 494**. Otherwise, like numbered elements shown in **Figure 4B** correspond to those described and shown in **Figure 3B** and will not be described further herein.

Figure 4C is a side elevational view of the overlap point of one of the outer diameter protection members illustrated in **Figure 4A** as noted in **Figure 4A.** As shown in **Figure 4C**, a first end **496** and a second end **498** of a protection member **405** define mating angles at an overlapping region of the protection member when the protection member is wrapped around the core. Thus, the protection member is able to extend around the entirety of the sharp edge of the core without a bump discontinuity at the overlapping region and, further, without any exposed sharp edge portion which might otherwise cause abrasion to a wire wrapped therearound. As shown in **Figure 4C**, the mating angles comprise 45 degree angles. It is to be understood that use of angles from about 15 degrees to about 75 degrees may be particularly advantageous in providing a simplified manufacturing methodology for providing protection member strips of a desired length which may be used interchangeably around inner or outer diameter features of a core to which the protection members are to be applied.

Substantially L-shaped protection members in accordance with various embodiments of the present invention are further illustrated in **Figures 5A** and **5B**. As shown in **Figure 5A**, the L-shaped protection member **500** includes a short leg **502** and a long leg **504** extending substantially transversely therefrom. An adhesive layer **506** is positioned along an inner surface **502a** of the short leg **502** while no adhesive layer is shown on the inner surface **504a** of the long leg **504** for the embodiments illustrated in **Figure 5A**.

Referring now to **Figure 5B**, further embodiments of L-shaped protection members according to the present invention will now be further described. The protection member **510** in **Figure 5B** includes a short leg **512** and a long leg **514**. For the embodiments illustrated in **Figure 5B** an adhesive layer **516** is placed along the inner surface **514a** of the long leg **514** which adhesive layer **516** may alternatively be provided along the inner surfaces of both the short leg **512** and the long leg **514** and may further, alternatively, be placed first on the core before application of the protection members to provide an adhesive layer therebetween. Furthermore, the embodiments illustrated in **Figure 5B** differ from those shown in **Figure 5A** in that they include tapered surfaces **518** and **520** provided by having the short leg **512** and the long leg **514** narrow at the ends thereof. Such a taper may be utilized to facilitate wrapping of an elongate member, such as a coated wire, around the protection members when they are installed on a core.

A section of strip stock defining a protection member having a channel or rail shape according to embodiments of the present invention, such as those illustrated in **Figure 3B**, is further illustrated in **Figure 6**. As shown in **Figure 6**, the protection member **600** includes a first leg **602**, a second leg **604** at an opposite end therefrom and a channel portion **606** extending therebetween. While not shown in **Figure 6**, it is to be understood that an adhesive layer may be presented on the inner surface of the first **602** and second **604** leg and/or the channel portion **606**.

Referring now to **Figure** 7, an apparatus for fabricating a polymeric protection member in accordance with the present invention will now be described. The apparatus **700** includes a spool **702** having a length of extruded crosslinked polymeric material **704** having a profile shaped in either an L-shaped or a channel shape as described previously. The extruded polymeric material **704** is fed from the spool **702** into a cutting station **706**, for example, utilizing a motor drive and rotation of the

spool **702**. The cutting station **706** includes a cutting tool **708** having a cutting blade **710** positioned at an angle alpha (α) relative to the plane over which the polymeric material **704** travels through the cutting station **706**. A desired length (L) of material, for example, a length corresponding to the circumferential length of the sharp edge to be protected, is measured out in the cutting station **706** and a cut is made at the angle α through the material **704** by the cutting blade **710**. The strip **704** is then advanced a desired length for a next piece to be fabricated and again cut at the angle α. Thus, each strip cut in the cutting station **706** is provided with first and second ends defining mating angles for use in an overlapping region of the protection members when the protection members are wrapped around a core so as to facilitate providing a mating region without a bump discontinuity in the overlapping area.

Referring now to **Figure 8**, operations related to assembling an electromagnetic device including a sharp edged core and at least one wire wrapped thereon according to embodiments of the present invention will now be further described. Operations begin at block **800** by placing a polymeric protection member around a sharp edge of the core which extends circumferentially around an inner diameter or an outer diameter of the core. If more circumferentially sharp edges exist on the core which have not yet been covered (block **805**), protection members are placed around such other edges (block **800**). The protection members, as described previously with reference to **Figures 3A** and **3B** through **6**, include at least one short leg position adjacent to an end of the core. The short leg has a length selected to provide a substantially flat surface on the end of the core when the protection member is wrapped around the core. One or more wires are then wrapped around the core (block **815**). The wires are wrapped around the core so as to be magnetically coupled thereto. They are further wrapped around the outer surfaces of the polymeric protection members so as to be displaced from the sharp edges of the core.

In various embodiments, the protection members may be applied directly to the core by resting an inner surface thereof against the sharp edges defined in a perimeter of the core. Each of the protection members may be cut to a length that matches the circumference of the inner or outer diameter to be protected before applying the protective strips to the sharp edges. In further embodiments, an adhesive layer may be placed on an inner surface of the polymeric protection members before placing them on the core so as to secure the protection members to the core.

Alternatively, or in addition to the adhesive layer, a tape, such as a glass tape, may be wrapped around the protection members before the wire is wrapped around the core.

Referring now to **Figure 9**, methods for fabricating a polymeric protection member for a device including a core having circumferentially extending sharp edges around an inner diameter and around an outer diameter thereof around which elongate members are wrapped will now be described for various embodiments of the present invention. Note that the device may be an electromagnetic device and the elongate member may be a wire or wires wrapped around the conductive core of the electromagnetic device.

Operations begin by determining a circumferential length of one of the sharp edges of the core (block **900**). A length of a polymeric protection strip stock corresponding to the determined circumferential length is measured out (block **910**). The polymeric protection strip stock is cut to the measured length to provide the protection member (block **920**). The polymeric protection strip stock is cut at an angle selected to define mating angles at an overlapping region of the protection member when the cut protection member is wrapped around the core. This may provide for a protection member which extends around the entirety of one of the sharp edges of the core without a bump discontinuity being introduced at the overlapping region where the ends of the polymeric protection strip stock meet. An apparatus such as that illustrated in **Figure 7** above may be suitable for use in carrying out the method described with reference to **Figure 9.**

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended

claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.